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Report 1996

EFFECTS OF CORROSION AND ANTI-ICING INHIBITORS
ON THE WATER COALESCING CHARACTERISTICS OF
MILITARY STANDARD FILTER/COALESCER ELEMENTS

by

Shirley B. Boulware

February 1971

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U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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**U. S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA**

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**EFFECTS OF CORROSION AND ANTI-ICING INHIBITORS
ON THE WATER COALESCING CHARACTERISTICS OF
MILITARY STANDARD FILTER/COALESCER ELEMENTS**

Final Report

Task IJ662708D50602

February 1971

Distributed by

**The Commanding Officer
U. S. Army Mobility Equipment Research and Development Center**

Prepared by

**Shirley B. Boulware
Fuels Handling Equipment Division
Mechanical Technology Laboratory**

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SUMMARY

This final report covers a study of the effects of seven corrosion inhibitors and corrosion/anti-icing inhibitor combinations on the coalescing characteristics of the DOD-type filter/coalescer elements used to decontaminate liquid hydrocarbon fuels. The corrosion inhibitors for use in military jet fuels are specified in Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble." They are identified by their trade names and manufacturers as Santolene-C, Monsanto Chemical Co.; RP-2 and AFA-1, E. I. DuPont de Nemours & Co.; Lubrizol, Lubrizol Corp.; Tolad-244, Petrolite Corp.; TRI-182, Texaco, Inc.; and Unicor-M, Universal Oil Products Co. The anti-icing inhibitor used conforms to Specification MIL-I-27686, "Inhibitor, Fuel System, Icing," and was obtained from Phillips Petroleum Co. One-percent water-removal tests and water separometer index (modified) (WSIM) investigations and analyses were conducted.

This research was carried out by the Fuels Surveillance and Technology Branch, Fuels Handling Equipment Division, U. S. Army Mobility Equipment Research and Development Center (USAMERDC), Fort Belvoir, Virginia.

The report concludes that:

- a. The corrosion and corrosion/anti-icing combination inhibitors did not produce adverse effects on the ability of military standard filter/coalescer elements to remove 1-percent water from JP-5 fuel that had been treated with fuller's earth.
- b. The free-water content of the fuel passed through the filter/coalescer elements during the 1-percent water injection tests ranged from 0 to 4.4 parts per million, which is within specification limits.
- c. The WSIM's of the inhibited JP-5 fuel during the tests were between 16 and 88.
- d. The low, free-water content did not correlate directly with the relatively low WSIM's.
- e. The WSIM cannot be used solely to determine the ability of a military standard filter/coalescer element to decontaminate inhibited JP-5 after it has been treated with fuller's earth. However, the WSIM does give an indication of the ability of a filter/coalescer element to decontaminate uninhibited JP-5.

FOREWORD

Authority for the evaluations described in this report is contained in CDOG paragraph 1610(e) which states: "Every means of . . . improving the handling of POL must be exploited."

The work was conducted under Task 1J662708D50602, "Fuels Decontamination Research," under the general supervision of T. H. Jefferson, Chief, Fuels Surveillance and Technology Branch, Fuels Handling Equipment Division.

Other personnel participating in the program were Shirley B. Boulware, Project Chemist, and John Zellars, William Stoney, and Lloyd Johnson, Test Mechanics.

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**EFFECTS OF CORROSION AND ANTI-ICING INHIBITORS
ON THE WATER COALESCING CHARACTERISTICS OF
MILITARY STANDARD FILTER/COALESCER ELEMENTS**

I. INTRODUCTION

1. Subject. This final report covers a study of the effects of the seven corrosion inhibitors specified in Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble," and the anti-icing inhibitor specified in Specification MIL-I-27686, "Inhibitor, Fuel System, Icing," on the water-removal characteristics of standard filter/coalescer elements used in military standard filter/separators.

2. Purpose of Tests. Chemical additives are incorporated in fuels to supplement and improve their performance. Too frequently, in field service, these additives have been found to adversely affect the ability of military, standard-dimension, filter/coalescer elements to remove contaminants to the extent required by Specification MIL-F-8901, "Filter/Separators, Aviation and Motor Fuel, Ground and Shipboard Use, Performance Requirements and Test Procedures For." The purpose of the tests conducted in this study was to determine the magnitude of the adverse effect of the additives. JP-5 fuel was used as a test fuel, and the effects of seven different corrosion inhibitors and corrosion/anti-icing inhibitor combinations specified for use in military jet fuels were studied. The concentrations of corrosion inhibitors were prescribed by the qualified products list (QPL) of inhibitors qualified under Specification MIL-I-25017.

The corrosion inhibitors used were Santolene-C, Monsanto Chemical Co.; Lubrizol, Lubrizol Corp.; Tolad-244, Petrolite Corp.; TRI-182, Texaco Inc.; Unicor-M, Universal Oil Products Co.; and RP-2 and AFA-1, E. I. DuPont de Nemours & Co. The anti-icing inhibitor was Phillips-55, obtained from Phillips Petroleum Co.

3. Background. Specification MIL-I-25017 contains a list of seven corrosion inhibitors that are approved for use in fuels conforming to Specification VV-G-76, "Automotive Gasoline"; MIL-G-3056, "Automotive Combat Gasoline"; MIL-G-5572, "Aviation Gasoline"; and MIL-J-5624, "JP-4 and JP-5 Turbine Fuels." RP-2, AFA-1, Lubrizol, Tolad-244, and TRI-182 corrosion inhibitors conform to Specifications VV-G-76, MIL-G-3056, and MIL-G-5572. Santolene-C and Unicor-M corrosion inhibitors conform to VV-G-76, MIL-G-3056, and MIL-J-5624 (QPL, August 1963). Each corrosion-inhibitor/JP-5-fuel combination and corrosion/anti-icing-inhibitor/JP-5-fuel combination was utilized in the tests. Specification MIL-F-8901 states that the only corrosion inhibitor to be used in combination with JP-5 fuel is Santolene-C. A Santolene-C/anti-icing-inhibitor combination and the additional six corrosion and corrosion/anti-icing inhibitors, in combination with JP-5 fuel, have never been used to

evaluate the performance of the military standard filter/coalescer elements by this installation.*

II. INVESTIGATION

4. Description of Test Facility. The test facility consisted primarily of a closed test loop (portions of which were glass), a 100-gallon storage tank, a 20-gallon-per-minute (gpm) centrifugal pump, water-injection equipment, sample withdrawal apparatus, a clean up filter/separator, and suitable instrumentation (see figure, page 3, for schematic drawing).

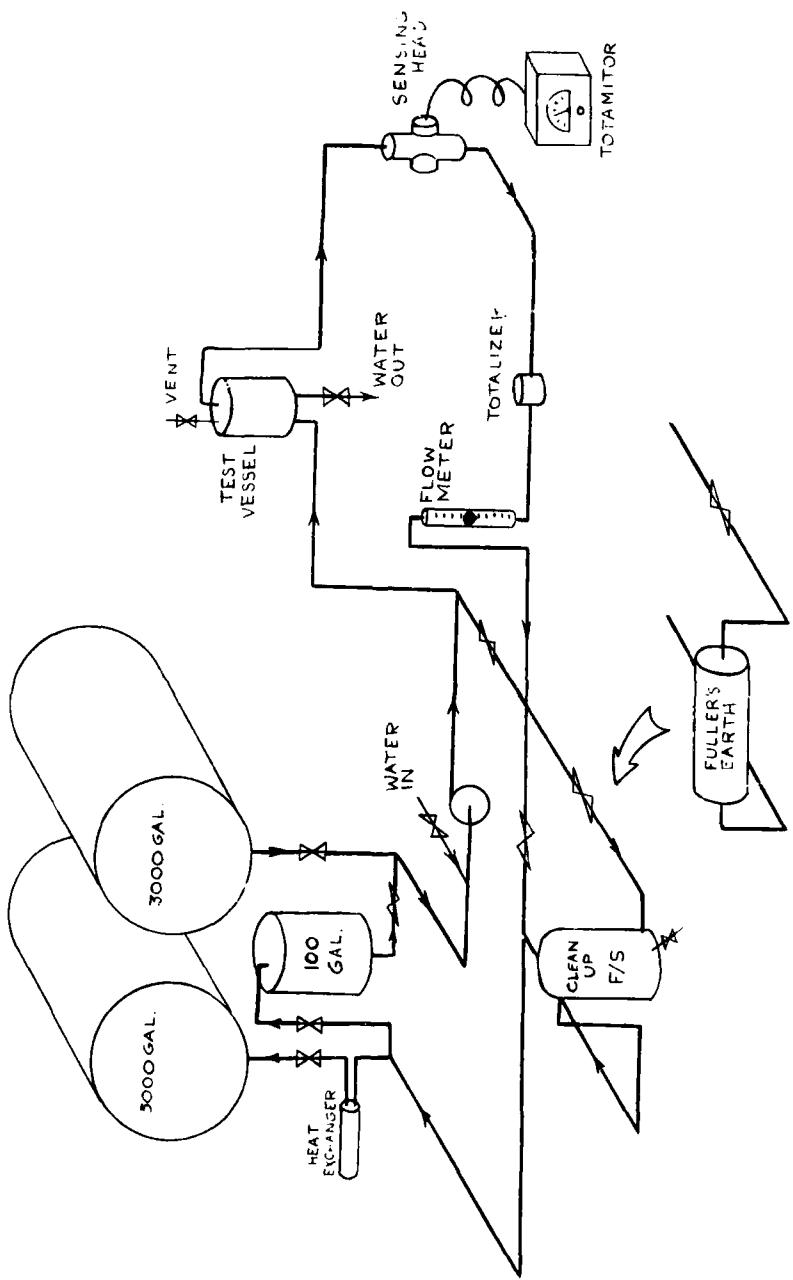
5. Test Filter/Coalescer Elements. The military, standard-dimension filter/coalescer elements used in the test series were Fram Model No. CC-511B, Bendix Model No. 045800-4, and Filters, Inc., Model I-4208, fabricated to conform to the requirements of Specification MIL-F-52308, "Filter Element, Fluid Pressure."

6. Performance Requirement. The water-removal performance requirement of Specification MIL-F-8901 states that the filter/coalescer element shall decontaminate inhibited fuel into which 1-percent water is being injected at rated fuel flow. When analyzed with in-line instrumentation, the effluent fuel shall contain not more than 5 parts per million (ppm), by volume, of undissolved water. The differential pressure across the filter/separator test vessel, with a new element installed and clean fuel (containing no undissolved water and not more than 0.5 milligrams per liter of solids contamination), shall not exceed 10 pounds per square inch (psi) at any flow rate up to 115 percent of rated flow, when measured across the inlet and outlet connections.

7. Test Fuel and Contaminant. JP-5 fuel conforming to Specification MIL-T-5624 was used as the test fuel. The fuel was treated with fuller's earth, and the WSIM prior to the addition of inhibitors was 96. Data are recorded stating WSIM's after the addition of specific inhibitor concentrations.

The water injected into the test fuel during tests was supplied by the Fort Belvoir water utility system. Prior to use in the test as an injected contaminant, water was filtered to a residual-solids level of less than 1 milligram per liter. The pH factor varied from 6.5 to 7.0.

* The filter/coalescer elements used in this investigation were made in accordance with the performance specification MIL-F-8901A. One of the purposes of this series of tests was to determine whether the existing elements under specification MIL-F-8901A would meet the performance requirements under the new specification MIL-F-8901B, which had not been officially published when these tests were conducted.



Schematic drawing of test facility.

8. Sample Analysis Procedures. Samples were analyzed for water-separation properties and free-water content. The following methods were employed:

a. Water-separation properties of the fuel were determined with a water separometer. This instrument measures the WSIM, which is an indication of the ability of a fuel or a fuel/additive combination to release entrained or emulsified water when the fuel is passed through a coalescer-type water separator.

b. Free-water content of the filter/separator effluent during the test was monitored by a Bowser Totamitor (Model 871) installed in the effluent portion of the system. This instrument operates on a light-scattering principle—a beam of light is difused or reflected by minute water droplets suspended in the fuel. The magnitude of light scattering is indicated on a dial (galvanometer) scaled to read in parts per million of free water.

9. Test Procedures and Results. Prior to the initiation of tests, 3000 gallons of JP-5 fuel were treated by passing the fuel through fuller's earth filters to obtain a minimum WSIM number of not less than 85. At the start of each test, 90 gallons of this treated fuel were pumped into the 100-gallon storage tank, which was part of the closed test loop, and the appropriate quantities of corrosion and anti-icing inhibitors were blended for 20 minutes by circulation while bypassing the test vessel and cleanup filter/separator.

Upon completion of blending, three 1-gallon samples were taken for WSIM analyses. The fuel was then pumped through the test system, including the cleanup filter/separator, at 2-gpm or 20-gpm flow rates, according to the size of the filter/coalescer element, to obtain the blank Totamitor and pressure readings. (The 2-gpm elements were cut proportionately to size from 20-gpm elements.) One-percent water was then injected for 30 minutes at the pump inlet. Totamitor and pressure readings were taken every 5 minutes for the duration of the 30-minute, water-injection period. Several 15-minute tests were run.

A new filter/coalescer element was used with the test run for each corrosion inhibitor; also, a new element was used for each corrosion/anti-icing inhibitor concentration. It was first exposed to the 1-percent, water-removal test using test fuel containing the minimum concentration of corrosion inhibitor, as prescribed in Specification MIL-I-25017, and 0.15-percent anti-icing inhibitor, where applicable. At the completion of each corrosion-inhibitor test, the entire test system (loop) was thoroughly cleaned and flushed with water to remove any residual quantity of corrosion and anti-icing inhibitors prior to conducting the next test.

In order to verify the test data from the above procedure, tests were set up wherein the entire volume of 3000 gallons of fuel was inhibited initially, and several manufacturers' filter/coalescer elements were tested. The purpose of the initial inhibition was to see whether the same type of results was obtained on a large volume of inhibited fuel, as compared to results obtained from 90 gallons of inhibited fuel.

The JP-5 fuel was treated with fuller's earth until the WSIM was not less than a minimum of 85; the anti-icing inhibitor was washed out of the fuel by injecting 3-percent water at the pump inlet. The fuel was then inhibited with 20 pounds of RP-2 corrosion inhibitor, and several water-removal tests were run. Anti-icing inhibitor was added (0.15 percent), and several more water-removal tests were run on the corrosion/anti-icing-inhibited fuel.

Results of the tests are recorded in the Appendix to this report (Tables I through XXIV).

III. DISCUSSION

16. Free-Water Content and WSIM Data. Theoretically, free water is undissolved water in excess of the water in solution in a fuel. The free-water content, as measured by the Totamitor, equals the total-water content minus the quantity of water in solution. The adjusted free-water content (total free-water content less the blank) of the test fuel in this study ranged from 0 to 4.4 ppm. Although the water separometer can be modified to semiquantitatively measure free-water content, its main purpose was to measure the ease with which a fuel will release free water.

Uninhibited JP-5 fuel received directly from the refinery without a fuller's earth treatment generally has a WSIM between 85 and 100 and is thought to be relatively surfactant-free—that is, free of surface-active agents. It is acceptable in that it can usually be decontaminated without difficulty by a filter/separator, using military standard filter/coalescer elements. JP-5 fuel not previously treated with fuller's earth, and with a WSIM between 70 and 84, is unpredictable, in that both passing and failing performances have been experienced in filter/sePARATOR operation. The JP-5 fuel specification requirement for WSIM is a minimum of 85. In general, untreated JP-5 fuel would be difficult to decontaminate if the WSIM was between 0 and 69. However, this is not true, in reference to treated JP-5 fuel/additive combinations, as is shown by the results obtained in this study. Tests using JP-5 fuel inhibited with corrosion or corrosion/anti-icing-inhibitor combinations and having WSIM's ranging from 16 to 88, passed 1-percent, water-removal requirements. These results contradict statements concerning untreated JP-5 fuel given earlier in this paragraph. The author theorizes that the successful water-removal tests were due mainly to the fact that the JP-5 test

fuel had been previously treated with fuller's earth. The fuller's earth removed all objectionable surfactants, which most likely would have plated out and/or adversely affected filter/coalescer element performance. Examples of these types of objectionable surfactants are sodium sulfonates, which are refinery residuals. It can be seen that it cannot be determined from the WSIM data alone whether a corrosion inhibitor will adversely affect JP-5 fuel to the extent that it cannot be decontaminated by a filter/coalescer element.

IV. CONCLUSIONS

11. Conclusions. It is concluded that:

- a. The corrosion and corrosion/anti-icing combination inhibitors did not produce adverse effects on the ability of military standard filter/coalescer elements to remove 1-percent water from JP-5 fuel that had been treated with fuller's earth.
- b. The free-water content of the fuel passed through the filter/coalescer elements during the 1-percent water injection tests ranged from 0 to 4.4 ppm, which is within specification limits.
- c. The WSIM's of the inhibited JP-5 fuel during the tests were between 16 and 88.
- d. The low, free-water content did not correlate directly with the relatively low WSIM's.
- e. The WSIM cannot be used solely to determine the ability of a military standard filter/coalescer element to decontaminate inhibited JP-5 after it has been treated with fuller's earth. However, the WSIM does give an indication of the ability of a filter/coalescer element to decontaminate uninhibited JP-5.

APPENDIX

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**Table I. Santolene-C Data
(Filters, Inc., F/C Element)**

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp* (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	20	92	2.0	0.80	61
4	5	20	92	2.5	0.90	—
4	10	20	92	2.5	0.90	—
4	15	20	92	2.5	0.90	—
16	0	20	85	2.0	0.90	34
16	5	20	85	3.0	0.95	—
16	10	20	85	3.0	0.95	—
16	15	20	85	3.0	0.95	—

* In several instances throughout this series of tests, the fuel temperature exceeded the 70° to 90° F range specified in Specification MIL-F-8901, because the test loop was not equipped with any type of heat exchanger.

**Table II. AFA-I Data
(Filters, Inc., F/C Element)**

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp* (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	20	92	2.0	0.9	37
4	5	20	92	2.0	0.9	—
4	10	20	93	2.0	0.9	—
4	15	20	93	2.0	0.9	—
16	0	20	84	2.0	0.7	43
16	5	20	84	2.5	1.1	—
16	10	20	84	2.5	1.2	—
16	15	20	84	2.5	1.3	—

* In several instances throughout this series of tests, the fuel temperature exceeded the 70° to 90° F range specified in Specification MIL-F-8901, because the test loop was not equipped with any type of heat exchanger.

Table III. Lubrizol Data
(Filters, Inc., F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp* (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	20	91	1.5	1.0	67
5	5	20	90	2.0	0.9	—
5	10	20	90	2.5	0.9	—
5	15	20	90	2.5	0.9	—
20	0	20	80	2.5	1.0	45
20	5	20	80	3.5	2.5	—
20	10	20	80	3.5	2.7	—
20	15	20	80	3.5	2.8	—

* In several instances throughout this series of tests, the fuel temperature exceeded the 70° to 90° F range specified in specification MIL-F-8901, because the test loop was not equipped with any type of heat exchanger.

Table IV. TRI-182 Data
(Filters, Inc., F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
17.5	0	20	78	2.0	0.80	70
17.5	5	20	79	2.5	0.85	—
17.5	10	20	79	2.5	0.90	—
17.5	15	20	79	3.0	1.00	—
20.0	0	20	80	2.0	0.75	68
20.0	5	20	81	2.5	2.10	—
20.0	10	20	81	2.5	2.60	—
20.0	15	20	81	2.5	2.50	—

Table V. Tolad-244 Data
(Filters, Inc., F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	20	76	2.0	0.90	62
5	5	20	76	2.5	0.95	—
5	10	20	77	3.0	0.90	—
5	15	20	77	3.0	0.95	—
20	0	20	81	2.5	1.30	56
20	5	20	82	3.5	3.50	—
20	10	20	82	3.5	3.40	—
20	15	20	82	3.5	3.30	—

**Table VI. Unicor-M Data
(Filters, Inc., F/C Element)**

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
9	0	20	76	2.0	0.85	16
9	5	20	77	2.5	0.90	—
9	10	20	77	2.5	0.90	—
9	15	20	78	2.5	0.90	—
20	0	20	80	2.0	0.75	23
20	5	20	81	3.0	1.00	—
20	10	20	81	3.0	1.00	—
20	15	20	81	3.0	1.10	—

Table VII. RP-2 Data
(Filters, Inc., F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
7	0	20	79	3.0	0.80	57
7	5	20	79	4.0	0.85	—
7	10	20	79	4.0	0.80	—
7	15	20	79	4.3	0.80	—
20	0	20	86	4.5	0.85	49
20	5	20	86	5.0	1.00	—
20	10	20	86	5.0	0.90	—
20	15	20	86	5.0	0.90	—

Table VIII. Santolene-C Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	20	68	2.5	1.1	52
4	5	20	68	6.5	1.3	—
4	10	20	68	6.5	1.2	—
4	15	20	68	7.0	1.2	—
4	20	20	68	7.0	1.2	—
4	25	20	68	7.5	1.2	—
4	30	20	68	7.5	1.3	—
16	0	20	60	5.0	1.2	29
16	5	20	61	7.0	1.3	—
16	10	20	62	7.5	1.3	—
16	15	20	63	7.5	1.3	—
16	20	20	63	7.5	1.3	—
16	25	20	64	8.0	1.3	—
16	30	20	65	8.0	1.3	—

Table IX. AFA-1 Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	20	57	3.0	0.85	42
4	5	20	59	5.0	1.00	—
4	10	20	60	5.0	1.00	—
4	15	20	60	5.0	1.00	—
4	20	20	61	5.0	0.90	—
4	25	20	62	5.5	1.00	—
4	30	20	62	5.5	1.00	—
16	0	20	62	3.5	0.85	54
16	5	20	63	5.0	0.95	—
16	10	20	63	5.0	0.90	—
16	15	20	65	5.5	0.90	—
16	20	20	66	5.5	0.90	—
16	25	20	66	5.5	0.90	—
16	30	20	66	5.5	0.90	—

Table X. Lubrizol Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	20	65	3.5	0.80	75
5	5	20	66	4.0	0.85	-
5	10	20	66	4.0	0.85	-
5	15	20	67	4.0	0.85	-
5	20	20	68	4.5	0.85	-
5	25	20	68	4.5	0.85	-
5	30	20	68	5.0	0.85	-
20	0	20	64	-	1.50	40
20	5	20	65	4.5	3.50	-
20	10	20	65	5.0	3.90	-
20	15	20	65	5.0	3.80	-
20	20	20	65	5.0	3.50	-
20	25	20	65	5.0	3.00	-
20	30	20	65	5.0	2.80	-

Table XI. TRI-182 Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
17.5	0	20	78	2.0	0.80	71
17.5	5	20	78	3.0	0.90	—
17.5	10	20	77	3.5	0.90	—
17.5	15	20	77	4.0	0.90	—
17.5	20	20	77	4.0	0.90	—
17.5	25	20	77	4.0	0.90	—
17.5	30	20	77	4.0	0.90	—
20.0	0	20	69	4.0	1.00	65
20.0	5	20	69	5.5	1.90	—
20.0	10	20	69	5.5	1.90	—
20.0	15	20	69	5.5	1.85	—
20.0	20	20	69	6.0	1.90	—
20.0	25	20	69	6.0	1.80	—
20.0	30	20	69	6.0	1.80	—

Table XII. Tolad-244 Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	20	80	3.0	0.80	88
5	5	20	80	4.0	0.85	—
5	10	20	80	4.0	0.80	—
5	15	20	80	4.0	0.80	—
5	20	20	80	4.0	0.80	—
5	25	20	80	4.5	0.80	—
5	30	20	80	4.5	0.80	—
20	0	20	75	4.5	0.90	44
20	5	20	75	4.5	1.25	—
20	10	20	75	4.5	1.25	—
20	15	20	75	5.0	1.25	—
20	20	20	75	5.0	1.25	—
20	25	20	75	5.0	1.25	—
20	30	20	75	5.0	1.25	—

Table XIII. Unicor-M Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
9	0	20	78	2.5	0.80	47
9	5	20	76	4.0	0.90	—
9	10	20	76	5.0	0.90	—
9	15	20	76	5.0	0.90	—
9	20	20	76	5.0	0.90	—
9	25	20	74	5.0	0.92	—
9	30	20	74	5.5	0.95	—
20	0	20	72	5.0	0.80	33
20	5	20	72	6.0	2.40	—
20	10	20	71	6.0	2.30	—
20	15	20	71	6.5	2.30	—
20	20	20	70	6.5	2.00	—
20	25	20	70	6.5	2.00	—
20	30	20	70	7.0	1.90	—

Table XIV. RP-2 Data
(Fram F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
7	0	20	76	2.0	0.75	42
	5	20	74	3.0	0.80	—
	10	20	73	3.5	0.80	—
	15	20	73	3.5	0.80	—
	20	20	73	3.5	0.80	—
	25	20	73	4.0	0.75	—
	30	20	73	4.0	0.75	—
20	0	20	64	3.5	0.65	32
	5	20	64	4.5	0.90	—
	10	20	64	5.0	0.90	—
	15	20	64	5.0	0.85	—
	20	20	64	5.0	0.85	—
	25	20	64	5.0	0.85	—
	30	20	64	5.0	0.90	—

Table XV. Santolene-C and AFA-1 Data
(Filters, Inc., F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor* (ppm)	WSIM
4 San-C	0	2	78	1	0.80	—
4 San-C	2	2	78	2	>30.00	—
					Failure	
4 San-C	0	2	78	2	0.80	—
4 San-C	5	2	78	4	18.00	—
4 San-C	10	2	78	4	18.00	—
					Failure	
4 AFA-1	0	2	80	1	0.90	—
4 AFA-1	5	2	80	2	>30.00	—
					Failure	

* Failures were attributed to defective endcap seals.

**Table XVI. Santolene-C and Anti-Icing Additive Data
(Bendix F/C Element)**

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	2	60	3.0	0.9	52
4	5	2	61	4.0	0.9	—
4	10	2	61	4.0	1.1	—
4	15	2	61	4.0	1.1	—
4	20	2	61	4.0	1.1	—
4	25	2	61	4.0	1.0	—
4	30	2	61	4.0	1.0	—
16	0	2	64	2.0	0.9	42
16	5	2	67	4.0	1.8	—
16	10	2	67	5.0	1.5	—
16	15	2	67	5.0	1.5	—
16	20	2	67	5.0	1.4	—
16	25	2	67	5.0	1.4	—
16	30	2	67	5.0	1.4	—

Table XVII. AFA-1 and Anti-Icing Additive Data
(Bendix F/C Element)

Inhibitor Concentration (lb. 1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	2	66	3.0	0.9	58
4	5	2	67	3.0	3.5	—
4	10	2	67	3.0	3.5	—
4	15	2	67	3.0	3.5	—
4	20	2	68	3.0	3.8	—
4	25	2	68	3.0	4.2	—
4	30	2	68	3.0	4.0	—
16	0	2	64	3.0	0.9	49
16	5	2	64	3.0	2.8	—
16	10	2	64	3.0	2.8	—
16	15	2	65	3.5	3.0	—
16	20	2	65	3.5	3.3	—
16	25	2	65	3.5	3.2	—
16	30	2	65	3.5	3.3	—

Table XVIII. Lubrizol and Anti-Icing Additive Data
(Bendix F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	2	72	2.0	0.85	63
5	5	2	72	2.0	0.85	-
5	10	2	72	2.0	0.80	-
5	15	2	72	2.0	0.85	-
5	20	2	72	2.0	0.80	-
5	25	2	72	2.5	0.80	-
5	30	2	72	2.5	0.85	-
20	0	2	62	2.5	0.80	52
20	5	2	63	2.5	0.90	-
20	10	2	64	2.5	2.50	-
20	15	2	65	2.5	3.20	-
20	20	2	65	2.5	3.80	-
20	25	2	65	3.0	5.00	-
20	30	2	65	3.0	5.20	-

Table XIX. TRI-182 and Anti-Icing Additive Data
(Bendix F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
17.5	0	2	74		0.85	69
17.5	5	2	74		0.85	—
17.5	10	2	74		0.90	—
17.5	15	2	74		1.20	—
17.5	20	2	74		1.20	—
17.5	25	2	74		1.20	—
17.5	30	2	74		1.00	—
20.0	0	2	70		0.90	79
20.0	5	2	69		1.40	—
20.0	10	2	69		1.40	—
20.0	15	2	69		1.80	—
20.0	20	2	69		1.80	—
20.0	25	2	69		2.30	—
20.0	30	2	69		2.80	—

Table XX. Tolad-244 and Anti-Icing Additive Data
(Bendix F/C Element)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	2	72	2.0	0.90	70
	5	2	72	2.5	0.90	—
	10	2	72	2.5	1.00	—
	15	2	72	2.5	1.00	—
	20	2	72	3.0	1.20	—
	25	2	72	3.0	1.10	—
	30	2	72	3.0	1.10	—
20	0	2	78	2.0	0.75	62
	5	2	78	2.0	1.10	—
	10	2	77	2.0	1.30	—
	15	2	77	2.0	2.00	—
	20	2	77	2.0	1.70	—
	25	2	77	2.0	1.80	—
	30	2	77	2.0	2.10	—

**Table XXI. Unicor-M and Anti-Icing Additive Data
(Bendix F/C Element)**

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
9	0	2	80	2	0.95	54
9	2	2	80	—	>30 Failure*	—
9	0	2	80	2.0	1.00	54
9	5	2	80	2.5	1.10	—
9	10	2	80	2.5	1.00	—
9	15	2	80	2.5	1.10	—
9	20	2	80	2.7	1.10	—
9	25	2	80	2.8	1.10	—
9	30	2	80	2.8	1.00	—
20	0	2	85	1.0	1.00	30
20	5	2	85	2.0	1.00	—
20	10	2	86	2.2	1.00	—
20	15	2	86	2.4	1.10	—
20	20	2	86	2.4	1.10	—
20	25	2	86	2.4	1.00	—
20	30	2	86	2.4	1.00	—

* Possible defective element.

**Table XXII. RP-2 and Anti-Icing Additive Data
(Bendix F/C Element)**

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
7	0	2	80	1.0	1.1	25
7	5	2	80	2.0	1.3	—
7	10	2	80	2.0	1.4	—
7	15	2	80	2.0	1.2	—
7	20	2	80	2.0	1.2	—
7	25	2	80	2.0	1.2	—
7	30	2	80	2.0	1.2	—
20	0	2	88	1.0	1.1	29
20	5	2	88	2.0	1.4	—
20	10	2	88	2.0	2.2	—
20	15	2	88	2.0	1.5	—
20	20	2	88	2.0	1.5	—
20	25	2	88	1.8	1.8	—
20	30	2	88	1.9	1.5	—

Table XXIII. Comparison Data, RP-2
(Bendix and Filters, Inc., F/C Elements)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp* (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
Bendix F/C Element						
20	0	2	96	1.5	1.2	—
20	5	2	94	2.0	1.4	—
20	10	2	94	2.0	1.8	—
20	15	2	94	2.2	1.9	—
20	20	2	94	2.2	2.9	—
20	25	2	94	2.2	5.6	—
20	30	2	94	2.2	6.5	—
Failure						
Bendix F/C Element						
20	0	2	102	0	1.1	—
20	5	2	102	2.0	1.2	—
20	10	2	100	2.0	3.5	—
20	15	2	100	2.0	2.3	—
20	20	2	100	2.0	1.8	—
20	25	2	100	2.0	2.5	—
20	30	2	100	2.0	4.5	—
Bendix F/C Elements						
20	0	2	95	1.0	0.9	—
20	5	2	—	2.0	1.1	—
20	10	2	—	2.0	1.3	—
20	15	2	—	2.0	1.4	—
20	20	2	—	2.0	2.7	—
20	25	2	—	2.0	3.1	—
20	30	2	91	2.0	3.5	—
Bendix F/C Elements						
20	0	20	80	1.5	0.9	—
20	5	20	80	2.5	1.1	—
20	10	20	80	2.5	1.2	—
20	15	20	80	2.5	1.2	—
20	20	20	80	2.5	1.2	—
20	25	20	80	2.5	3	—
20	30	20	80	2.5	1.3	—

* In several instances throughout this series of tests, the fuel temperature exceeded the 70° to 90° F range specified in Specification MIL-F-8901, because the test loop was not equipped with any type of heat exchanger.

Table XXIII (cont'd)

Inhibitor Concentration (lb/1000 bbl)	Time (min.)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
Bendix F/C Element						
20	0	20	82	3.0	1.1	—
20	5	20	83	3.0	1.5	—
20	10	20	83	3.0	1.7	—
20	15	20	83	3.0	1.8	—
20	20	20	83	3.0	1.9	—
20	25	20	83	3.0	2.1	—
20	30	20	83	3.0	2.4	—
Filters, Inc., F/C Element						
20	0	20	84	1.5	0.9	—
20	5	20	84	3.0	0.9	—
20	10	20	84	3.3	0.9	—
20	15	20	84	3.5	0.9	—
20	20	20	84	4.0	0.9	—
20	25	20	84	4.0	0.9	—
20	30	20	84	4.0	0.9	—

Table XXIV. Data Summary

Inhibitor	Concentration (lb/1000 bbl)	Corrosion Inhibitor			Free-Water Content (ppm) (Total Less Blank)			W SIM			Press Diff. (psi)		
		Filters, Inc.	Fram Inc.	Bendix Inc.	Filters, Inc.	Fram Inc.	Bendix Inc.	Filters, Inc.	Fram Inc.	Bendix Inc.	Filters, Inc.	Fram Inc.	Bendix Inc.
San-C	4.0	0.10	0.20	—	61	52	—	2.5	5.0	—	—	—	—
San-C	16.0	0.05	0.10	—	34	29	—	3.0	3.0	—	—	—	—
San-C/AIA	4.0	—	—	0.1	—	—	52	—	—	—	—	1.0	—
San-C/AIA	16.0	—	—	0.3	—	—	42	—	—	—	—	3.0	—
AFA-I	4.0	0.00	0.20	—	37	42	—	2.0	2.5	—	—	—	—
AFA-I	16.0	0.60	0.05	—	43	54	—	2.5	2.0	—	—	—	—
AFA-I/AIA	4.0	—	—	3.1	—	—	58	—	—	—	—	3.1	—
AFA-I/AIA	16.0	—	—	2.4	—	—	49	—	—	—	—	2.4	—
Lubrizol	5.0	0.00	0.50	—	67	75	—	2.5	1.5	—	—	—	—
Lubrizol	20.0	1.80	1.30	—	45	40	—	3.5	—	—	—	—	—
Lubrizol/AIA	5.0	—	—	0.0	—	—	63	—	—	—	—	0.5	—
Lubrizol/AIA	20.0	—	—	4.4	—	—	52	—	—	—	—	0.5	—
TRI-182	17.5	0.20	0.10	—	70	71	—	3.0	2.0	—	—	—	—
TRI-182	20.0	1.80	0.80	—	68	65	—	2.5	2.0	—	—	—	—
TRI-182/AIA	17.5	—	—	0.2	—	—	69	—	—	—	—	1.5	—
TRI-182/AIA	20.0	—	—	1.9	—	—	79	—	—	—	—	1.5	—
Tolad-244	5.0	0.05	0.00	—	62	88	—	3.0	1.5	—	—	—	—
Tolad-244	20.	2.00	0.4	—	56	44	—	3.5	0.5	—	—	—	—
Tolad-244/AIA	5	—	—	0.2	—	—	70	—	—	—	—	1.0	—
Tolad-244/AIA	20	—	—	1.4	—	—	62	—	—	—	—	0.0	—

Table XXIV (cont'd)

Inhibitor	Corrosion Inhibitor Concentration (lb/1000 bbl)	Free-Water Content (ppm) (Total Less Blank)			Filters, Inc.	WSIM	Filters, Inc.	Bendix	Filters, Inc.	Fram	Bendix	Filters, Inc.	Fram	Bendix	Press Diff. (psi)	
		Filters,	Fram	Bendix												
Unicor-M	9	0.05	0.2	-	16	47	-	2.5	3.0	-	-	-	-	-	-	-
Unicor-M	20	0.40	1.1	-	23	33	-	3.0	2.0	-	-	-	-	-	-	-
Unicor-M/AIA	9	-	-	0.0	-	-	-	54	-	-	-	-	-	-	0.8	-
Unicor-M/AIA	20	-	-	0.0	-	-	-	30	-	-	-	-	-	-	1.4	-
RP-2	7	0.00	0.0	-	57	42	-	4.3	2.0	-	-	-	-	-	-	-
RP-2	20	0.05	0.3	-	49	32	-	5.0	1.5	-	-	-	-	-	-	-
RP-2/AIA	7	-	-	0.1	-	-	-	25	-	-	-	-	-	-	1.0	-
RP-2/AIA	20	-	-	0.4	-	-	-	29	-	-	-	-	-	-	0.9	-

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Mobility Equipment Research and Development Center Fort Belvoir, Virginia		2a. REPORT SECURITY CLASSIFICATION Unclassified
2b. GROUP		
3. REPORT TITLE EFFECTS OF CORROSION AND ANTI-ICING INHIBITORS ON THE WATER COALESCING CHARACTERISTICS OF MILITARY STANDARD FILTER/COALESCER ELEMENTS		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report		
5. AUTHOR(S) (First name, middle initial, last name) Shirley B. Boudware		
6. REPORT DATE February 1971	7a. TOTAL NO. OF PAGES 42	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO.	8b. ORIGINATOR'S REPORT NUMBER(S) 1996	
b. PROJECT NO. 11662708D50602	9d. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c.	d.	
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.		
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY U. S. Army Mobility Equipment Research and Development Center
13. ABSTRACT <p>This final report covers a study of the effects of seven corrosion inhibitors and corrosion/anti-icing inhibitor combinations on the coalescing characteristics of the DOD-type filter coalescer elements used to decontaminate liquid hydrocarbon fuels. The corrosion inhibitors are specified for use in military jet fuels, Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble." The anti-icing inhibitor used conforms to Specification MIL-I-27686, "Inhibitor, Fuel System, Icing."</p> <p>The report concludes that:</p> <ul style="list-style-type: none">a. The corrosion and corrosion/anti-icing combination inhibitors did not produce adverse effects on the ability of military standard filter coalescer elements to remove 1-percent water from JP-5 fuel that had been treated with fuller's earth.b. The free water content of the fuel passed through the filter/coalescer elements during the 1-percent water injection tests ranged from 0 to 4.4 ppm, which is within specification limits.c. The WSIM's of the inhibited JP-5 fuel during the tests were between 16 and 88.d. The low, free water content did not correlate directly with the relatively low WSIM's.e. The WSIM cannot be used solely to determine the ability of a military standard filter/coalescer element to decontaminate inhibited JP-5 after it has been treated with fuller's earth. However, the WSIM does give an indication of the ability of a filter/coalescer element to decontaminate uninhibited JP-5.		

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REPLACES DD FORM 1473, 1 JAN 64, WHICH IS
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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Filter Coalescer Elements Filter Separator Corrosion Inhibitor WSIM Free Water Content						